AD-A105 953 SRI INTERNATIONAL MENLO PARK CA F/G 20/11

LARGE AMPLITUDE COMPRESSION AND SHEAR WAVE PROPAGATION IN IMPAC--ETC(U)

OCT 81 Y M GUPTA DAAG29-78-0030

UNCLASSIFIED ARO-15513.2-E NL

1 OF 1

AD A

105953

ADA105953

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

LEVEL II

(12)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER: 15513.2-E | 2. GOVT ACCESSION NO.: AD-A105 953 |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle): Large Amplitude Compression and Shear Wave Propagation in Impact-Loaded PMMA | 5. TYPE OF REPORT & PERIOD COVERED: Final Report: 1 Jul 78 - 30 Sep 81 |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s): Y. M. Gupta | 8. CONTRACT OR GRANT NUMBER(s): DAAG29 78 C 0030 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: SRI International, Menlo Park, CA 94025 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS: U. S. Army Research Office, Post Office Box 12211, Research Triangle Park, NC 27709 | 12. REPORT DATE: Oct 81 |
| | 13. NUMBER OF PAGES: 4 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | 15. SECURITY CLASS. (of this report): Unclassified |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

DTIC ELECTE OCT 21 1981 S D

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

NA

18. SUPPLEMENTARY NOTES

The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The goal of this research was to develop an improved understanding of the high strain rate material response of polymers by studying the propagation of large-amplitude, one-dimensional compression and shear waves in impact-loaded polymethy methacrylate (PMMA). Experimental techniques were designed and developed to permit measurement of large-amplitude shear waves. Measurements were made of the shear particle velocity at the impact surface and in the sample interior. The measurement of shear wave velocities permitted the first determination of the

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DTIC FILE COPY

10 20 81

20. ABSTRACT CONTINUED

shear and bulk modulus in the shocked state. The shear wave profiles measured at several gage locations in the sample were integrated (using a Lagrangian analysis for compression and shear waves) to provide shear stress-strain response in the shocked state. These results are the first of their kind and provide an important constraint on the shear (or deviator) response of the material.

| Accession For | | |
|---|---|---|
| NTIS GRA&I | ☒ | |
| DTIC TAB | ☐ | |
| Unannounced | ☐ | |
| Justification | | |
| By | | |
| Distribution/ | | |
| Availability Codes | | |
| Dist | Avail and/or Special | |
| A | | |

SRI International

(11) October 1981

(9) Final Report, 1 Jul 78 - 30 Sep 81

(6) LARGE AMPLITUDE COMPRESSION AND SHEAR WAVE PROPAGATION IN IMPACT-LOADED PMMA

By: (10) Y. M. Gupta, Principal Investigator

(12) 7

Prepared for:

U.S. ARMY RESEARCH OFFICE
P. O. Box 1221
Research Triangle Park, NC 27709

(17) ARO

Attention: Dr. F. W. Schmiedeshoff
Engineering Sciences Division

(19) 15513.2-E

SRI Project No. PYU-7606
Contract (15) DAAG29-78-C-0030

Approved:

D. R. Curran, Director
Shock Physics and Geophysics Department

G. R. Abrahamson
Vice President
Physical Sciences Division





SRI International

333 Ravenswood Ave. • Menlo Park, CA 94025
(415) 859-6200 • TWX: 910-373-2046 • Telex: 334 486

410281

SUMMARY

The goal of this research was to develop an improved understanding of the high strain rate material response of polymers by studying the propagation of large-amplitude, one-dimensional compression and shear waves in impact-loaded polymethyl methacrylate (PMMA). Measurements of in-material biwaves provide a unique and direct determination of the dynamic shear properties and frictional behavior, as well as the dynamic compressive response. Most of the objectives were successfully completed, as discussed below.

Experimental techniques were designed and developed to permit measurement of large-amplitude shear waves. Unlike uniaxial strain compression measurements, accurate measurements of shear wave profiles are quite difficult for two reasons: first, the very nature of shear wave measurements makes it difficult not to perturb the measurement in the region of interest* and second, the amplitudes of the shear waves are considerably smaller (a few percent) than those of the compression waves. We have been successful in measuring the shear particle velocity at the impact surface and in the sample interior. Although both these measurements are unique, we emphasize the impact surface measurement. Without this measurement, the initial conditions for the experiment are not completely specified, and the material response cannot be uniquely determined.

*The continuity of tangential particle volocity is more difficult to satisfy than the continuity of normal particle velocity.

The measurement of shear wave velocities permitted the first determination of the shear and bulk modulus in the shocked state. These moduli have been measured to density compressions of approximately 18%. Over this range, the shear modulus increases linearly in contrast to the bulk modulus, which increases in a nonlinear manner. The bulk modulus versus density data were integrated to provide the mean stress-volume relation corresponding to the longitudinal stress-volume states under shock loading. Our results show that the use of a static hydrostat (as is commonly done) is invalid. Instead, a rate-dependent relation needs to be used.

The shear wave profiles measured at several gage locations in the sample were integrated (using a Lagrangian analysis for compression and shear waves*) to provide shear stress-strain response in the shocked state. These results are the first of their kind and provide an important constraint on the shear (or deviator) response of the material. In contrast, the uniaxial strain results depend only on the compressive stress (mean stress plus stress deviators) and cannot be used to uniquely fit a material model. (The shear stress-strain results showed that, even at 20 kbar compressive stress, the PMMA can sustain large-amplitude shear waves.)

Although the results of this work have provided many new pieces of information, this work is only a start. Further experimental and analytic work needs to be done on PMMA to better understand and model the response of at least one material somewhat completely under shock

---

*Y.M. Gupta, paper in preparation.

loading. In particular, the temperature measurements reported by Bloomquist and Sheffield [J. Appl. Phys. 51, 5260 (1980)] need to be reconciled with the shear wave data.

A paper describing the work accomplished during the past 12 months is being prepared and will be submitted to the *Journal of Applied Physics* in the near future.

The technical support of D. Henley, D. Walter, and A. Urweider throughout this research project is gratefully acknowledged. B. Y. Lew is thanked for her programming assistance in all the data reduction and analyses. Discussions with M. C. Cowperthwaite were helpful in developing the Lagrangian analysis.

## PUBLICATIONS

Y. M. Gupta, D. D. Keough, D. Henley, and D. F. Walter, "One-Dimensional Compression and Shear Wave Propagation in Polymethyl Metacrylate (PMMA)," Bull. Amer. Phys. Soc. 24, 716 (1979); contributed paper for the topical conference on Shock Waves in Condensed Matter, held in Pullman, Washington, June 1979.

Y. M. Gupta, "Research Applications of Combined Compression and Shear Wave Propagation in Solids," Bull. Amer. Phys. Soc. 24, 717 (1979); invited paper for the topical conference on Shock Waves in Condensed Matter, held in Pullman, Washington, June 1979.

Y. M. Gupta, "Determination of the Impact Response of PMMA Using Combined Compression and Shear Loading," J. Appl. Phys. 51, 5352 (1980).

Y. M. Gupta, "Dynamic Shear Response of Shocked PMMA," manuscript to be submitted to J. Appl. Phys.

DATE
ILME